THE OSCILLOGRAPHER

Vol. 11, No. 2 APRIL-JUNE, 1949

BOUNCE OF A RELAY ARM

SEE PAGE 2

Du Mont Display at the 1949 I. R. E. Show

Shown above is the display of the Instrument and Tube Divisions of Allen B. Du Mont Laboratories, Inc., at the 1949 I.R.E. show. The show, held at Grand Central Palace, New York, from March 7 to March 9, was visited by some 16,000 persons, to set an all-time record for attendance.

The complete line of Du Mont cathode-ray oscillographs, industrial cathode-ray tubes, and allied equipment was on display.

Of particular interest to visitors at the Du Mont display was the demonstration of the Du Mont Type 281-A Cathode-ray Indicator operating in conjunction with a Type 286-A High-voltage Power Supply, illustrating the high light-output capacities of that combination for displaying

(*Continued on P.* 19)

THE OSCILLOGRAPHER

A publication devoted exclusively to the cathode-ray oscillograph, providing the latest information on developments in equipment, applications, and techniques.

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CONTENTS

	Page
Du Mont Display at 1949 I.R.E. Show	2
Luminescent Screens for Cathode-ray Oscillography	3
Du Mont Special Products Section Develops New Four-Beam Cathode-ray Indicator	12
The New Du Mont Type 264-B Voltage Calibrator	13
Diode Limiter Circuits in Oscillographic Applications	14
Table of Contents, Vol. 1, No. 1 — Vol. 10, No. 4	20
Bibliography	23

NOTICE

The offices and factory of the Instrument Division of Allen B. Du Mont Laboratories, Inc. will be closed for vacation from July 11 to July 24, inclusive.

ON THE COVER

This oscillogram, photographed from the screen of a Du Mont Type 275-A Polar-coordinate Indicator, shows the bounce of the moving arm of a relay directly after activation. The small semi-circle at left represents time before activation. Radial deflections at top indicate bouncing at the time of activation. The larger semi-circle at right represents the rest period of the activated relay arm after bouncing had subsided. This oscillogram was obtained by driving the two-phase generator by a synchronous motor, and applying a d-c potential through the relay contacts to the radial input of the indicator.

LUMINESCENT SCREENS FOR CATHODE-RAY OSCILLOGRAPHY

A Review of the Basic Properties of Screen Materials For Cathode-Ray Tubes, and Their Relation to Oscillograph Performance

By R. Feldt*

TO KEEP pace with the extremely rapid expansion of cathode-ray oscillography during the past decade, manufacturers have been striving to produce new and different screen materials to meet the requirements of new applications. As a result there is now available a wide variety of screen materials with highly specialized characteristics.

It may be said that there are four basic characteristics which determine the performance of a phosphorescent screen material for cathode-ray tubes: (1) Luminous efficiency; (2) color; (3) persistence; (4) resistance to screen burning and fatigue. Since each of these characteristics is dependant upon various other factors, it would be well to discuss briefly the general operation of phosphors.

It can be said that a substance luminesces if part of the exciting radiant energy is not transformed into heat but is re-emitted in the form of radiant energy. Among the very numerous luminescent materials, or phosphors, one group has been found particularly interesting from the technical standpoint — the crystal phosphors. The luminescence of these substances is not based on a particular property of their atoms or molecules, but on their crystalline structure, and the whole crystal, or at least a part of it, participates in the process of luminescence, involving a great number of atoms. To the crystal phosphors belong particularly the zinc and zinc cadmium sulfides, the silicates, and the tungstates.

It is interesting to note that an ideal crystal is unable to luminesce unless the periodicity of the crystal lattice is disturbed by the introduction of a foreign body. These foreign bodies essential to luminescence are metal atoms, known as activators, which are added in extremely small amounts and built into the crystal lattice. It is the activator which determines the color of the luminescence, and the color of one basic phosphor can be shifted through the entire spectrum simply by employing various activators in various amounts. For example, zinc sulfide activated with copper luminesces green, while it shifts to blue when activated with silver. If the amount of silver is further increased, the color shifts to red. It is also possible to use two activators simultaneously with the same basic screen material. An example of this is the Type P2 phosphor, which, when ex-

*Head, Instrument Division, Allen B. Du Mont Laboratories, Inc. This article is adapted from papers delivered by Mr. Feldt before the National Electronics Conference, 1947, and the Southwestern Conference of the I.R.E. in 1948.

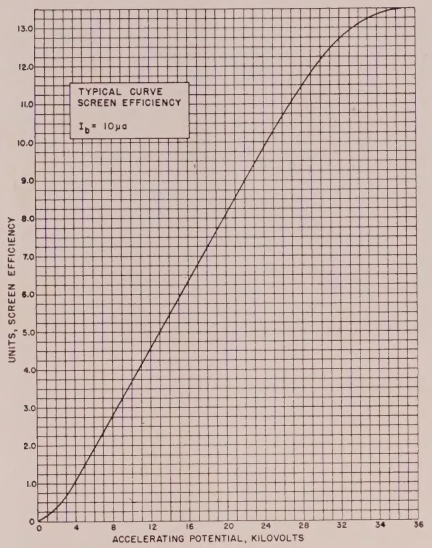


Figure 1. A typical curve showing the relationship between screen efficiency and accelerating potential.

cited, generates both a blue light of short persistence and a yellow light of long persistence.

Just as only a very small amount of metal is required as an activator, so extremely small amounts of impurities in the phosphor can "poison" the screen, producing undesirable spots. The most elaborate care — even to complete air conditioning of the plant — must be taken during manufacture to avoid this defect.

Screen Thickness — The thickness of the layer of phosphor is extremely important to the efficiency of the cathode-ray screen. Since the phosphor is excited on one side by the electron beam, and viewed from the other side, the phosphor coating must be a translucent layer. The electrons which impinge on the phosphor penetrate to a depth that is determined by the velocity of the electrons, and which varies as the square of the accelerating potential. It would appear from this that the highest screen efficiency for a given voltage would be obtained from a coating thickness just fully penetrated by the electrons. However, this is not exactly the case for several reasons. First, the electrons of the beam do not all travel at the same speed (the beam is not monochromatic). Also, the particles that make up the screen are not tightly packed, with the result that there are a great many empty spaces between them. Moreover, the electrons do not always strike an active phosphor center.

With present-day techniques, therefore, it is customary to make a coating somewhat heavier than would be required from the stand-point of electron penetration alone. If, on the other hand, the coating is made too thick, a screen layer results, part of which is excited and light-generating, while the remainder is not excited, and absorbs the light emitted from the excited portion.

If we plot screen efficiency vs. coating thickness, at a given accelerating voltage, we find an optimum value for a certain thickness, with the efficiency decreasing for both thicker and thinner screens. As would be expected, this optimum thickness increases with increases in accelerating voltage.

From this the following important conclusions may be drawn concerning the operation of cathode-ray tubes:

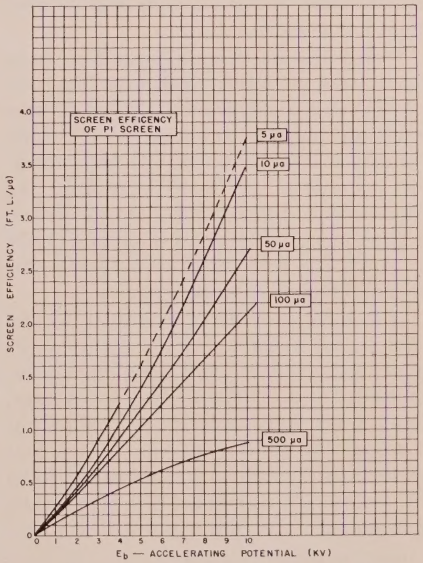


Figure 2. Graph showing relationship between beam current and screen efficiency.

(1) Lack of uniformity in screen thickness will manifest itself in irregular brightness of the luminescent pattern.

(2) The proper thickness of the phosphorescent coating must be determined in accordance with the accelerating voltage for which the tube is rated.

For instance, a tube coated for low-voltage operation will not be satisfactory at high voltage (over 6-10kv), since most of the electrons traverse the thin screen and hit the glass face of the tube, causing burning of the glass and a consequent further reduction in efficiency. Similarly, a tube designed for high-voltage operation is relatively inefficient at low voltages because so much of the light is absorbed by the unexcited portion of the screen.

Screen Excitation — The excitation of the screen and the release of the light energy can take place in a number of different ways. In the vast majority of cases, however, the light is either generated immediately with the start of the excitation and ceases with the end of the excitation (short persistence); or the light may not be immediately produced when excitation starts, but builds up gradually, with the light emission lasting even after the excitation has ceased (medium and long persistence).

In addition to light generated in the phosphor, part of the energy of the electron beam is transformed into heat and X-rays, or is given up in transmission to secondary electrons. The X-rays are of little practical importance as long as the applied accelerating potential is under 25,000 volts. Heat and secondary electrons, however, must be taken into careful consideration. The secondary electrons, which are released from the screen crystals by the impact of primary electrons, play a vital part in the stability of the screen potential. Also, these secondary electrons may strike other parts of the screen, thereby producing undesirable luminescence.

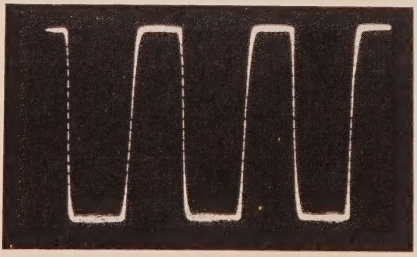


Figure 3. A 1000-cycle square wave. Note the difference in thicknesses of vertical and horizontal traces.

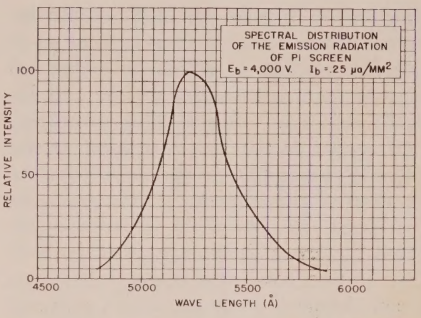


Figure 4. Spectral characteristic of the Type P1 phosphor.

The heat generated by the electron beam is of even greater importance. The efficiency of almost all screen phosphors depends very strongly upon their temperature, with their efficiency decreasing as the temperature rises. Thus, if the beam is permitted to strike the same spot for a time sufficient to increase materially the temperature, the light output from that spot will decrease.

Another important effect of heat is the quenching of phosphorescence. The higher the temperature, the shorter the persistence. As a result, practically all phosphors show considerably higher efficiency under intermittent excitation than under permanent excitation.

Light Output vs. Accelerating Potential — One of the basic characteristics which describes the performance of a screen material is the light output vs. accelerating potential. Below a certain voltage level which is of the order of about 100 volts, and which varies with different materials (it is sometimes as low as 10 volts) no light is generated. From there, up to several thousand volts, the light output increases as the square of the accelerating potential. Then, if the voltage

continues to increase, the light output increases proportionately. This applies up to a certain voltage, at which no additional increase in accelerating potential can increase the light output. This saturation level is due to the fact that most screen materials are insulators and can adopt the potential of the impinging electrons only if at least one secondary electron is released for every incoming primary electron. If this condition is not fulfilled, a screen charge is built up, which prevents any further increase of potential. Consequently, the light output cannot increase, regardless of any further increase in the potential applied to the primary electrons.

Another important characteristic of screen materials is the light output as a function of the beam current. As is apparent from figure 2, the screen efficiency in ftl/μa decreases substantially with increasing current. This is due to the heat developed in the screen material. The heat at the screen can be reduced, and the efficiency increased, by blanking the electron beam, permitting it to operate only during the time that the observed phenomenon takes place.

Spectral Characteristics — The spectral characteristics of the light output of the screen material is a very important factor in determining the selection of the right phosphor for a specific application. In general, phosphors produce continuous radiation spectra which extend over a wide range of the visible spectrum, and beyond. The peak efficiency of the phosphors commonly used for cathode-ray oscillography lies either in the blue or in the yellow-green part of the spectrum, since they are to be used for either visual observation or photographic recording.

Another point of importance is the spectral characteristic of the fluorescence during excitation and the phosphorescence after excitation. For example, the two most commonly used long-persistence screen materials, the Types P2 and P7, appear blue during fluorescence, and yellow during phosphorescence. With suitable filters, it is possible to separate the two components and to use either of them, or both. The use of filters also increases the contrast of the pattern by reducing the influence of ambient light, and eliminating the disturbing influence of the other component.

The phosphors used for cathode-ray tubes may be divided into three groups, as far as their persistence is concerned:

(1) Short persistence — decay within 100 μsec.*

(2) Medium persistence — decay within one millisec.

(3) Long persistence — decay within seconds or minutes.

Generally speaking, the stronger the excitation, the faster the decay. Increases in temperature shorten persistence. It might be well to mention, however, that changes in room temperature have little or no effect, since screen temperature may reach several hundred degrees, C, almost instantaneously under electron bombardment.

Another limiting factor is the quantity of energy which can be stored and released in the form of phosphorescence. There exists a definite saturation level insofar as phosphorescence is concerned, which cannot be increased by any means, since the phosphors are capable of storing a limited amount of energy.

Spot Size — Spot size, an exceedingly important factor in determining tube performance, is extremely difficult to measure or define accurately, since so many factors control it. The first factor which governs spot size is the actual design and construction of the electron gun, since it is here that the cross section of the beam is determined.

From the user's standpoint, the smallest possible spot size wtih the greatest possible brilliance, is most desirable. Generally speaking, brilliance of spot increases with increasing accelerating voltage and increasing beam current. Unfortunately, as beam current is increased, spot size too increases. While the spot size is controlled

*Figures describing phosphorescence are approximative, and can only within certain limits be considered material constants. Decay time is defined as the time interval from cessation of excitation until luminous output decreases to 10% of the initial value.

essentially by laws of electron optics, there is also an additional increase of spot size due largely to the repellant action which the electrons exert on each other. This may be overcome in part by increasing the accelerating potential. But this in turn has the undesirable effect of making the electrons less sensitive to the transverse deflecting forces.

Another factor which is of great importance in determining spot size is the thickness of the phosphorescent layer, since both electrons and light rays scatter in the screen material. As mentioned in the foregoing, the screens must be of different thicknesses for different accelerating voltages. A screen designed for high-voltage operation will result in a rather large spot if operated at low voltages. And similarly, a screen consisting of two or more layers such as the P7 will show a larger spot size than a single-layer screen such as the P2. For low voltages, a very thin screen should be used if a fine spot size is required.

The most important factor, however, governing the apparent spot size is the velocity at which the spot moves across the screen. This may be best demonstrated by taking as an example an oscillogram of a square wave (see Figure 3). Here, the vertical lines, where the spot travels at high speed, appear very thin, while the horizontal portions of the trace are thick. This is due to the uneven light distribution across the spot, which shows a Maxwellian distribution. If the spot were to stand still, the whole area corresponding to this bell-shaped characteristic would be excited (i.e., the spot size would be greatest). However, with the increasing speed of the beam traveling across the screen, only the center of the spot excites the phosphor sufficiently to be visible to the eye or to expose a photographic plate. Thus the apparent spot size decreases as the velocity of the beam increases. This permits the use of cathode-ray tubes with extremely high beam currents for the observation and recording of very-high-speed phenomena.

Halo — Halo is a phenomenon whose character has been little recognized but which should be mentioned in connection with apparent spot diameter. Halo may be described as a series of concentric rings of increasing diameter and decreasing intensity surrounding the spot. As a result of the presence of such rings, contrast is lower. Halo is particularly harmful when small pips are to be observed near a very bright line.

Halo is due essentially to reflections in the glass face of the tube, under the critical angle, with the diameter of the rings being proportional to the thickness of the face plate. Halo can be eliminated by removing optical contact between the face plate and the screen material, by making the face plate so thin that the halo diameter remains smaller than the spot diameter, or by making the face plate so thick that the diameter of the halo becomes greater than the tube diameter. Unfortunately, none of these solutions is particularly practical.

Commercial Phosphors — The most common application of the cathode-ray oscillograph is the visual observation of repetitive phenomena. Since the introduction of the cathode-ray oscillograph, zinc orthosilicate, Type P1, has been most frequently used for this purpose. The P1 phosphor is one of the most stable and efficient of screen materials. Its spectral characteristic is peaked around 5500A in the yellow-green portion of the visible spectrum, which corresponds closely to the region of maximum sensitivity of the human eye. The persistence of the P1 screen is medium, of the order of 30 milliseconds. This is sufficient to decrease flicker at low frequencies, and still avoid "smearing" if the pattern changes quickly.

In the observation of frequencies below 10 cps, the P1 screen becomes useless because of the excessive flicker of the pattern. If the frequency employed is still lower (below a few cps) the pattern is no longer recognizable, and all that is visible is the slowly moving spot.

For such instances, a screen with a long persistence characteristic is required. The Types P2 and P7 are the commercial phosphors most frequently used under these circumstances. These two types are quite

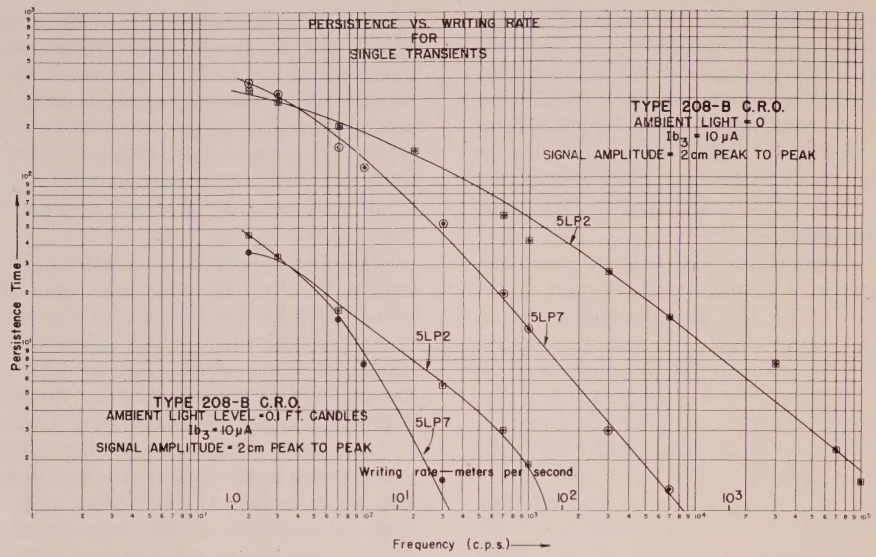


Figure 5. Graph comparing Types P2 and P7 screens at 1100 volts accelerating potential.

different in their design, since the P2 is a single layer, and P7 a double layer. They are both blue fluorescent and yellow phosphorescent. At low voltage, the P7 screen gives somewhat better results insofar as light output and persistence are concerned. The P7 has the further advantage of the so-called build-up, i.e. for repetitive phenomena, the excitation is cumulative until the phosphorescence is fully excited. The P2 screen has, however, the double advantage of smaller spot size and higher photographic efficiency, both due to the single-layer feature.

Long-persistence screens are particularly suitable for the study of single transients. By means of phosphorescence it is possible to obtain a lasting picture of phenomena that occur during a short time interval, without the necessity of making a photographic recording. Lightning discharges lasting fractions of microseconds, mechanical movements of millisecond duration, or vibrations taking seconds, all can be made to give visible impressions of sufficient duration. The same two phosphors, type P2 and type P7, are available for such purposes. Figure 5 compares these two phosphors at low voltage, under identical operating conditions, (accelerating potential, 1100 volts, beam current, 10 microamperes). The results are plotted for cases of total darkness and for ambient-light level of 0.1 foot-lambert. The graph shows the crossover point at about 30 cps. Below this frequency the type P2 phosphor is slightly inferior, but above this limit, its persistence is considerably longer. Figure 6 shows a comparison of the same screen types at high voltage (3kv and 16 kv). It may be seen that the crossover point shifts to higher frequencies with increasing voltage. At 16 kv, the cross-over lies at 100 kc. As before, the P2 is more efficient at higher frequencies. Both figures show the tremendous influence of the ambient-light level on useful persistence time. The following conclusions may be drawn from these data:

1. To take fullest advantage of long-persistence screens, it is advantageous to work in total darkness. If this is impractical, the use of optical filters is recommended.

2. As long as the accelerating potential can be raised sufficiently, there seems to be no practical limit to the speed of transients that can be observed.

3. For the observation of single transients, the Type P7 phosphor has a slight advantage at lower frequencies, while the P2 phosphor is substantially better at high frequencies. As a general rule, the use of the P2 phosphor is recommended.

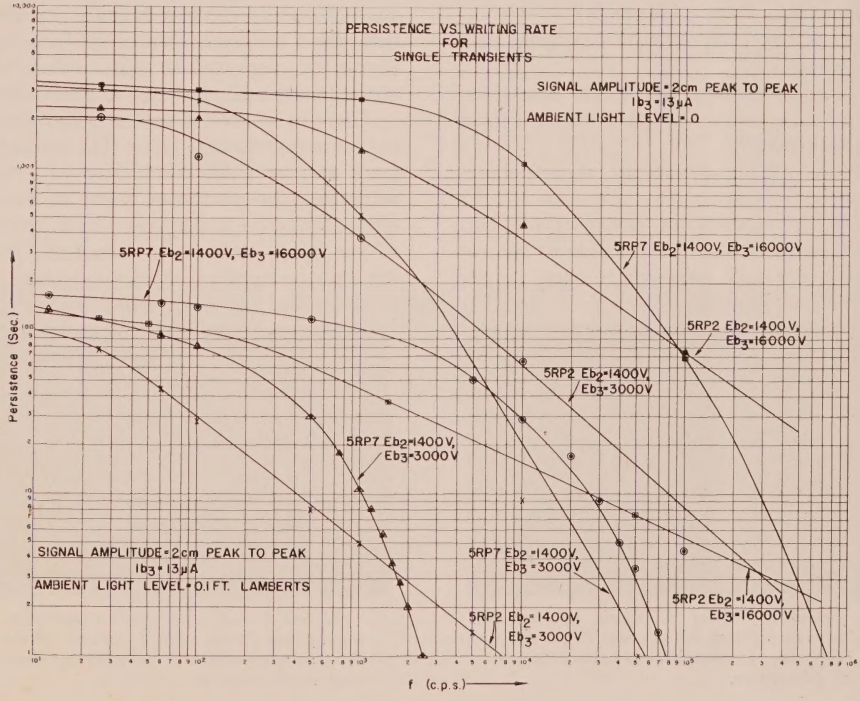
Photographic Recording — Many users of cathode-ray oscillographs will sooner or later find it desirable to make photographic recordings of oscillographic patterns. At that point, they are faced with two problems: the selection of the right screen, and the determination of the correct photographic exposure.

The determination of exposure times, covered in previous Oscillographer articles,[1,2] will not be discussed here.

In the selection of the proper screen material, we will first consider the moving-film type of camera, such as the Du Mont Type 314-A Oscillograph-record Camera. In this instance, only a short-persistence screen may be used. The importance of this is evidenced by Figure 7 which shows a 60-cps sinewave recorded from the medium-persistence Type P1 screen. Contrast this with the recording of a 3000-cps wave in Figure 8 taken from a short-persistence Type P11 screen. Obviously, the P11 is to be recommended highly for use with moving film-cameras. However, if sufficient light output is available, the Type P2 phosphor can also be used for the same purpose, if only the blue component of the light is used, while the yellow component is eliminated by a suitable blue filter, and if orthochromatic, blue-sensitive film is employed. The P2, under these circumstances, is roughly two or three times less efficient than the P11.

For single-frame photography, with a camera such as the Du Mont Type 271-A Oscillograph-record Camera, the P11 is again the most desirable phosphor from the standpoint of photographic efficiency. In comparison with the P11, the photographic characteristics of the other

Figure 6. Comparison of Types P2 and P7 at high accelerating potentials.


PERSISTENCE VS. WRITING RATE FOR SINGLE TRANSIENTS
SIGNAL AMPLITUDE = 2cm PEAK TO PEAK
Ib3 = 13μA
AMBIENT LIGHT LEVEL = 0
5RP7 Eb2 = 1400V, Eb3 = 16000V
5RP7 Eb2 = 1400V, Eb3 = 16000V
5RP2 Eb2 = 1400V, Eb3 = 16000V
5RP2 Eb2 = 1400V, Eb3 = 3000V
5RP7 Eb2 = 1400V, Eb3 = 3000V
SIGNAL AMPLITUDE = 2cm PEAK TO PEAK
Ib3 = 13μA
AMBIENT LIGHT LEVEL = 0.1 FT. LAMBERTS
5RP7 Eb2 = 1400V, Eb3 = 3000V
5RP2 Eb2 = 1400V, Eb3 = 16000V
5RP2 Eb2 = 1400V, Eb3 = 3000V
Persistence (Sec.)
f (c.p.s.)

important phosphors rate approximately as follows: P5 — .1; P1 — .3; P2 — .5; P11 — 1.0.

High-Voltage Screens — Several years ago, when Du Mont Laboratories undertook the development of high-voltage cathode-ray tubes, [3,4,5] a thorough investigation of screen materials was conducted in order to extend the use of these tubes into the fields of very high frequencies, studies of surge voltages, high-speed photographic recording, and projection oscillography.[4] In addition, visual and photographic recording efficiency, persistence, stability, screen burning, and other pertinent data were carefully studied.

This investigation showed the surprisingly low efficiency of certain commercial phosphors when operated at high accelerating voltages, as compared with the high efficiency of others. It was found that if any type of phosphor could be pointed to as a universal type for high-voltage oscillographic tubes, that type was the P2. The versatility of this phosphor is apparent from the following list of applications:

Visual observation of repetitive phenomena (medium persistence).

Projection oscillography (medium persistence).

Visual observation of single transients, including very fast phenomena (short persistence).

Photographic recording (short persistence).

By the selection of either of the two light components, it is possible to control both color and persistence over an extremely wide range.

Moreover, the P2 screen can be expected to perform satisfactorily at potentials ranging from 5000 to 35,000 volts. It should be borne in mind, however, that the P2 screen does have limitations and that all of the above factors should be taken into consideration when a screen is to be selected for a specific application.

As mentioned on page 5, paragraph 3, the potential of the screen depends upon the ability of the phosphor to produce a sufficient number of secondary electrons to compensate for the incoming primary electrons. At higher accelerating potentials a considerable difference may develop between the screen potential and the applied accelerating potential. This results in the failure of additional accelerating potential to produce additional light output from the fluorescent screen. Moreover, a considerable difference in potential may exist between the parts of the screen struck by electrons and the unexcited portions. This may set up local screen charges which prevent the beam from always striking the same point on the screen for the same deflection voltages. While, in modern cathode-ray tubes, this effect has been greatly minimized, it cannot be neglected in cases where very accurate measurements are to be made.

There exist several methods for obtaining an equipotential layer. The phosphor itself may be made conductive by proper mixtures; the phosphor may be coated on a conductive transparent layer applied to the glass wall, or a metallized coating may be applied on the phosphor, between it and the electron beam. This last

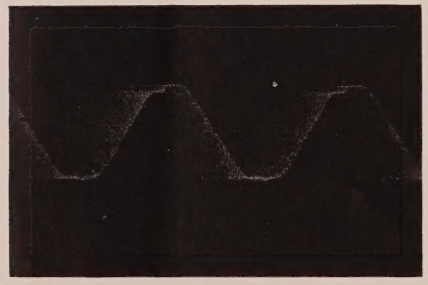


Figure 7. A 60-cycle sinewave recorded from P1 screen. Note blurring due to persistence characteristic of phosphor.

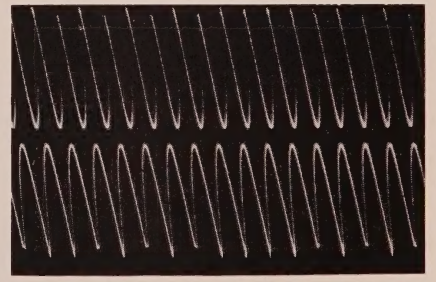


Figure 8. A 3000-cycle wave photographed from a P11 screen. With the short-persistence phosphor, blurring is eliminated.

method seems to present the greatest advantages. A thin metallic film of aluminum is deposited on the screen material so that it is situated between the phosphor and the oncoming electrons. This metallic layer not only makes it possible to use the screen itself as a final accelerating anode, but also eliminates local charges.

In addition, the metallic layer acts as a mirror, reflecting much light which is otherwise wasted, thereby increasing the total light output. Since the electrons must penetrate the metal layer before reaching the phosphor, the metallized layer must be sufficiently thin to pass the electrons without unduly decelerating them. On the other hand, it must be sufficiently thick to be homogeneous and to act as an optical mirror. The increase in light output due to metallization thus depends both on the accelerating potential and the thickness of the metal layer. Under optimum conditions, the increase in light output achieved by metallization may be of the order of 50% to 150%. The process is relatively expensive, since production shrinkage is materially increased. Thus it is felt that metallized tubes will be limited to special high-voltage applications where the utmost in brightness and accuracy in measurements is required.

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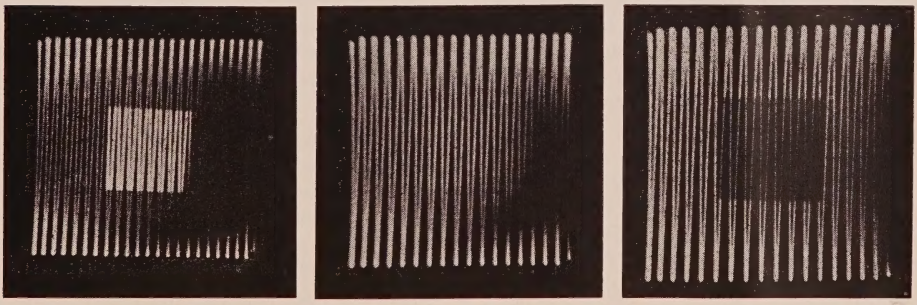


Figure 9. Oscillograms taken from a cathode-ray tube, metallized except for a small square at center of screen. Left: At 4000 volts accelerating potential, trace is brighter where metal coating is absent. Center: Cross-over point, where light output from both portions is same, is reached at 5500 volts. Right: Metallized portion is distinctly brighter (8000 volts).

DU MONT SPECIAL PRODUCTS SECTION DEVELOPS NEW FOUR-BEAM CATHODE-RAY INDICATOR

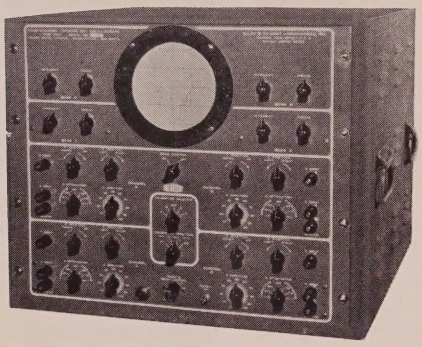


Figure 1. The new specially designed Four-Beam Indicator.

THE COMPLETE line of Du Mont cathode-ray oscillographs has been carefully designed to serve over as broad a range of applications as possible. But occasionally there arises an application so highly specialized that no commercially available instrument can meet its requirements. In such instances, the Special Products Section of the Instruments Division of Allen B. Du Mont Laboratories, Inc. will modify existing equipment or design wholly new equipment.

A new Four-Beam Cathode-ray Indicator is an example of such a special instrument. This indicator was designed, developed, and manufactured by the Special Products Section for a leading manufacturer of electrical and electronic equipment, and is capable of displaying simultaneously four independent phenomena on a single cathode-ray tube screen. The indicator is externally similar to the Du Mont Type 279 Dual-Beam Cathode-ray Oscillograph, but is equipped with the specially designed Du Mont Type K1027 Cathode-ray Tube, containing four independent electron guns, rather than the Type 5SP Dual-Beam Cathode-ray Tube.

The new indicator contains its own power supply and a horizontal amplifier for each of the four channels. Sweep circuits and vertical amplifiers are not provided in the indicator.

The instrument is intended for use with an oscillograph-record camera of the moving-film type, such as the Du Mont 314-A, where the motion of the film provides the time base, or with external time base generators, such as the Du Mont Type 215 Low-frequency Linear Time Base Generator. When the indicator is used with a time base generator, one generator must be provided for each channel, if independent control of the time bases is required.

The horizontal amplifiers of the new Four-beam Indicator are direct-coupled, with conductive or capacitive inputs to the four channels. As in the Du Mont Type 279 Dual-beam Oscillograph, each channel may be individually calibrated by means of an internal voltage calibrator.

Input to the Y axes is made at the terminals on a panel at the rear of the indicator. Selector switches permit choice of conductive or capacitive input coupling.

Z-axis amplifiers are not provided in the indicator, but intensity modulation may be accomplished by applying modulation signals to the Z-input terminals on the front panel.

Independent intensity and focus control for each channel are provided, and provision for stand-by operation is incorporated.

This Four-Beam Indicator is an example of the special equipment that the Special Products Section will create when the requirements of an application are beyond the capabilities of commercially available instruments. Details concerning the facilities of the Special Products Section may be had by communicating with the Instrument Division, Allen B. Du Mont Laboratories, Inc., 1000 Main Avenue, Clifton, New Jersey.

THE NEW DU MONT TYPE 264-B VOLTAGE CALIBRATOR

THE NEW Du Mont Type 264-B Voltage Calibrator, like the Type 264-A which it replaces, is an instrument for the measurement of the amplitude of a signal applied to any cathode-ray oscillograph.

The Type 264-B differs from the Type 264-A in that it may be adapted for either 110-volt or 230-volt operation by changing the connections to the power transformer. Also, the shape of the square-wave output has been improved by a minor change in the circuit constants.

Figure 1. The Du Mont Type 264-B Voltage Calibrator.

Measurement of the amplitude of a signal applied to a cathode-ray oscillograph may be readily accomplished with the Type 264-B. The most convenient procedure is to adjust the attenuator and gain controls of the oscillograph to give some suitable deflection factor in volts per inch, leaving those controls fixed for the measurements that follow. Thereafter the amplitude of an unknown signal can be read directly from the ruled scale. To do this, the square-wave output of the Voltage Calibrator is applied to the vertical input terminal of the oscillograph at a known amplitude, as read from the dial of the Calibrator. The vertical gain controls of the oscillograph are then adjusted so that the voltage produces a given deflection (say, one inch) on the screen as measured by a calibrated scale (such as the Du Mont Type 216-C Calibrated Scale). With the oscillograph thus calibrated, the amplitude of any signal applied to the oscillograph may be measured against the scale, so long as the setting of the vertical gain control is not changed.

The amplitude of a signal applied to an oscillograph may also be measured by substituting for it a square-wave voltage from the Calibrator, which is then adjusted to produce the same amount of deflection as the signal. The amplitude is then read from the Calibrator. In this procedure, the signal under study is connected to the Signal Input terminal on the panel of the Type 264-B, and the output of the Voltage Calibrator is connected to the vertical deflection terminal of the amplifier. By setting the Output Multiplier switch at "Signal Output" the signal is applied to the oscillograph. After the deflection produced by the signal has been noted, a square-wave voltage is applied to the oscillograph by setting the Output Multiplier switch on either X.001, X.01, X.1, or X1 (depending on the range of the signal under observation). The square-wave output of the Calibrator is then adjusted to produce the same deflection as that produced by the signal. The amplitude of the signal may then be read directly from the dial and the multiplier on the front panel of the Calibrator. No lead need be connected or disconnected during this process.

SPECIFICATIONS

Electrical Characteristics — Output square-wave at power-line frequency, with full-scale readings of 0.1 volt, 1 volt, 10 volts, or 100 volts. Amplitudes are variable from zero on each scale. Accuracy of output dial reading, ±5% of full scale on each range (including power-line voltage variations of ±10%). Input impedance to signal, 20 $\mu\mu$f.

Power Source — 115-or 230-volt power line, 50-60 cps. Power consumption, 20 watts.

Tubes — The following tubes are supplied with the Type 264-B: 6X4; OA2; 6AL5.

Physical Characteristics — Instrument enclosed in metal case. 4½" (height) x 8" (width) x 5¾" (depth). Weight, 5 lbs.

Catalog No.	Type No.	Description
1441-A	264-B	115 volts, 50-60 cps.
1442-A	264-B	230 volts, 50-60 cps.

Diode Limiter Circuits In Oscillographic Applications

By

H. P. Mansberg[1]

[*Editor's note: Frequently tests and measurements performed with the cathode-ray oscillograph may be greatly facilitated by the use of various accessory devices. Limiter and clipper circuits, delay lines, special sweep synchronizing and triggering circuits, voltage calibrators, balanced input adapters, transducers, and attenuators are but a few examples. The following article is the first of a series describing the design and function of such accessory devices.*]

The diode limiter or clipper is a simple, inexpensive circuit which has proved itself useful in a number of different applications.

For example, it is often desired to display a signal consisting of a combination of very high-amplitude and very low-amplitude levels. In order to study the detail of the low-amplitude portion, it becomes necessary to advance the Y-gain control on the oscillograph. This usually causes the amplifier to be either overloaded or blocked by the large-amplitude portions of the signal. In many cases the blocking lasts long enough to cause distortion, or, even complete loss of the low-level portion of the signal.

An example of this blocking action occurs in the case where transmission lines are tested by the pulse reflection method. In this test, a sharp pulse of high amplitude is fed into the sending end of the transmission line, and both the initial pulse and subsequent reflections are displayed on a single time base.[2] However, if the losses in the line are appreciable, or if the line is terminated with an impedance approaching the characteristic impedance, the reflections will be very low in amplitude as compared to the original

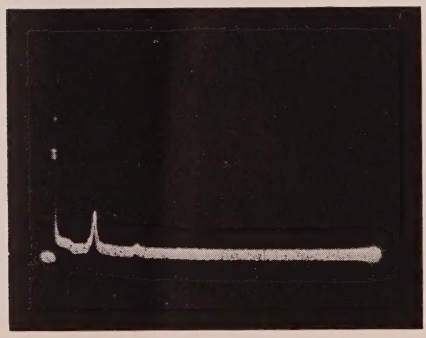


Figure 1. Initial test pulse and attenuated reflections on a transmission line. With gain sufficiently low to avoid amplifier blocking, only two reflections are visible.

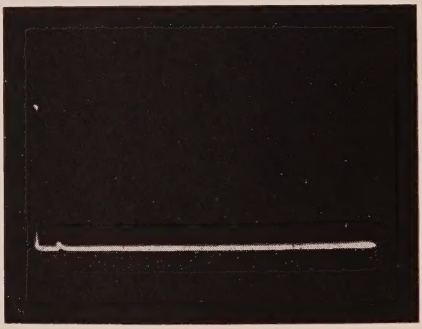


Figure 2. If gain is increased to determine whether there are more reflections, the test pulse blocks the amplifier, and only test pulse and first reflection are visible.

1 **Engineer,** Applications Engineering Section, Instrument Division, Allen B. Du Mont Laboratories, Inc.

2 "Transmission Line Measurements" by E. A. Ossmann, OSCILLOGRAPHER, May-June, 1945, Vol. 7, No. 3.

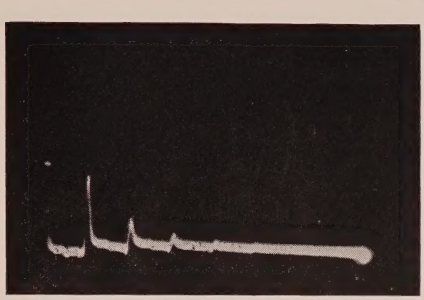


Figure 3. By the use of a diode limiter, biased to limit test pulse to a value at which amplifier will not block, clipped test pulse and four reflections are clearly visible, with fifth reflection barely visible.

test pulse. An example of this is shown in the oscillogram of Figure 1, which was made from the screen of a Du Mont Type 248-A Cathode-ray Oscillograph with a Type 271-A Camera.[3] Note that the initial pulse and only two reflections are visible, with the second one being extremely small. To determine whether there were any more reflections, and to study them in more detail, the Y-gain control was turned up to maximum. This caused the amplifier to block on the initial pulse as shown in Figure 2. Here, the initial pulse and the first reflection only, are visible. To overcome this difficulty, a diode limiter circuit was employed, which was biased so that as the initial pulse entered the Y-amplifier, it was limited to a value at which it would not overload or block the amplifier at full gain. The result was the oscillogram shown in Figure 3. Note that in this oscillogram, the clipped test pulse and four reflections can readily be observed, with a fifth reflection also barely visible. The basic circuit for the diode limiter used is shown in Figure 4. The bias control, R_1, determines the level at which the pulse is clipped.

If a negative test pulse is used, the limiting circuit shown in Figure 4 would not prevent the amplifier from overloading. In this case, a negative limiter or a combination negative-and-positive limiting circuit may be connected between the cable and the input of the oscillograph, as shown in Figure 5.

Figure 6 is an oscillogram illustrating the use of a negative test pulse in testing transmission lines by the pulse-reflection method. The limiter circuit shown in Figure 5 was constructed to serve as an accessory in setting up illustrations of cable testing by the pulse-reflection method. The pulses in these illustrations, obtained from the internal trigger generator of the Type 248-A Cathode-ray Oscillograph, were of the order of 50 volts amplitude and one micro-second in duration. In testing transmission lines by the pulse-reflection method, both positive and negative reflections may be observed due to polarity reversals at the terminating impedance of the transmission line. The combination positive and negative limiter circuit

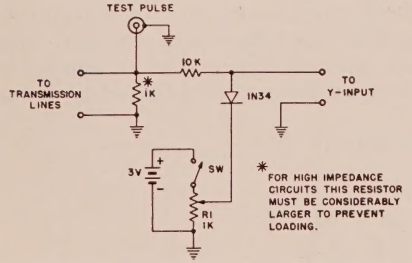


Figure 4. The basic circuit for a positive diode limiter. Bias control, R1, determines the level of clipping.

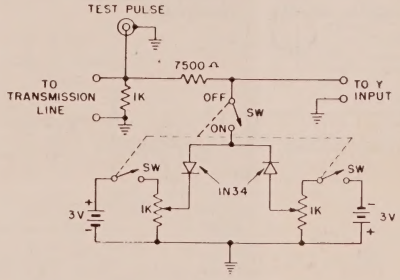


Figure 5. A combination positive and negative limiting circuit for clipping peaks of both polarities.

3 "The High-Voltage High-Speed Oscillograph" by H. Mansberg, OSCILLOGRAPHER, Jan.-Feb., 1947, Vol. 9, No. 1.

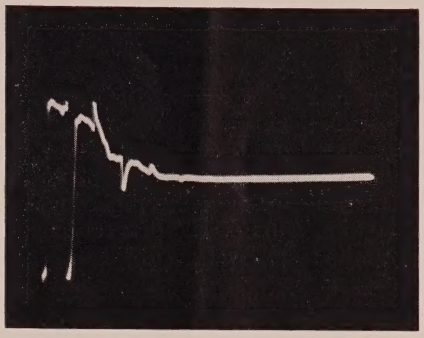


Figure 6. An oscillogram illustrating the use of negative pulses in testing transmission cables by pulse-reflection method.

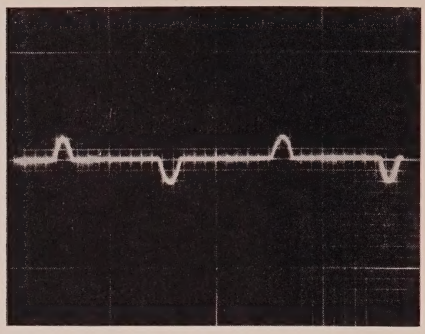


Figure 8. An oscillogram of the peaks of a 60-cycle sinewave, obtained by employing the circuit shown in Figure 7.

would be useful in any case where it became necessary to display without overloading or blocking, both positive and negative reflections of large amplitude.

In many cathode-ray oscillographs, the circuits are designed to provide excellent low-frequency response, necessitating the use of large coupling condensers and large grid input resistors. The long RC time constant causes the amplifiers to block if signals of large amplitude are applied without first being attenuated. This situation sometimes occurs with certain conditions of applied signal voltage and gain in the Du Mont Type 208-B Cathode-ray Oscillograph. In the case of the Type 208-B, this difficulty with blocking can be eliminated, when the excellent low-frequency response is not required, by decreasing values of either the grid resistances or the coupling condensers in the Y-amplifier stages. If low-frequency response cannot be sacrificed, however, a limiter such as that shown in the circuit of Figure 5 may be used. Here, the bias should be set so that the diode will limit at a level slightly above the level of the signal under observation. Thus, if a signal is suddenly applied which has components greater than this level, the limiting action will prevent the amplifier from blocking.

In studies made with the cathode-ray oscillograph, it often becomes necessary to observe in great detail the variations occurring at the peaks of a signal. The usual practice in this case is to increase the amplitude of the signal by advancing the Y gain, causing the signal to occupy several times the screen diameter. Then the Y-positioning control is adjusted so that just the peaks of the signal appear

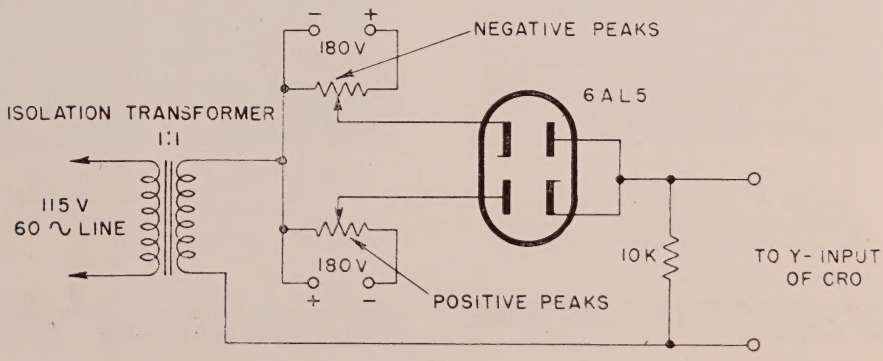


Figure 7. Combination negative and positive limiter, by means of which signal peaks alone may be applied to the oscillograph.

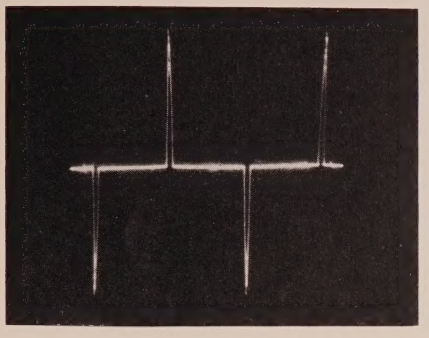


Figure 9. Same peaks as those in Figure 8, with gain at maximum. Variations of line voltage are apparent.

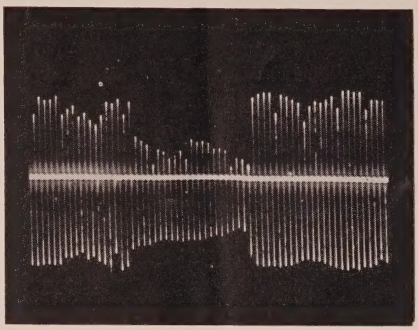
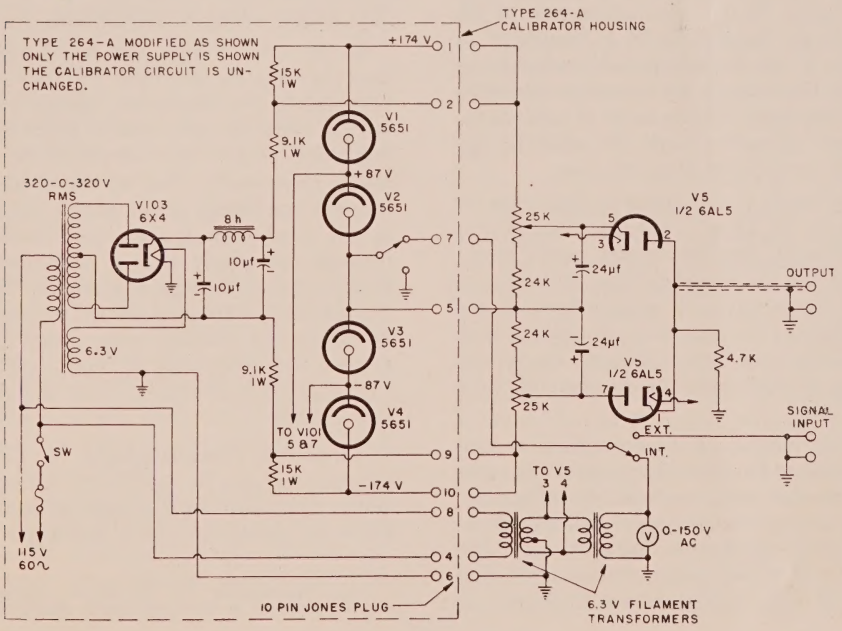


Figure 10. By decreasing the sweep frequency of the oscillograph, cyclical variations of line voltage may be observed.

on the screen and these peaks are further amplified and studied. However, it is obvious that such study would be greatly facilitated if just the peaks alone of the waveform were visible and amplified as much as desired, without being hindered by the remainder of the signal. Here again the diode limiter circuit may be profitably applied.

Line-Voltage Fluctuations — In one particular application it was necessary to observe minute fluctuations in the line voltage, (sometimes called "line bop"). These could not be studied by conventional methods, because the amplitude of these variations was so low and the fluctuations of such short duration that a meter was useless. A pair of diodes was connected between the line and the Y-in-

Figure 11. Modification of the Du Mont Type 264-A Voltage Calibrator for displaying and measuring line-voltage variations.



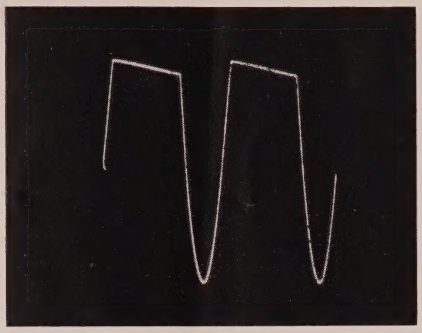


Figure 12. A clipped sinewave which has been passed through an amplifier having poor low-frequency response. Note the tilt in the flat top.

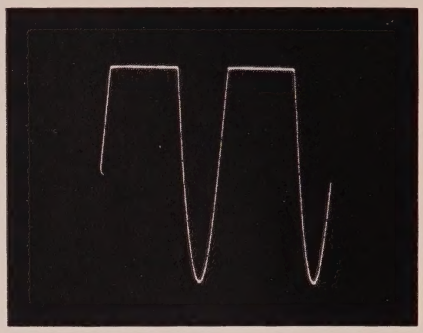


Figure 13. The same clipped sinewave passed through an amplifier having good low-frequency response. Here the flat top remains horizontal.

put of the oscillograph as shown in Figure 7. The bias control was adjusted so that only a small portion of the peak amplitude of the line was visible, as in the oscillogram of Figure 8. Then the Y-gain control was turned up to maximum and the peak variations in line voltage became visible, as in the oscillogram of Figure 9.

In this particular case, a periodic variation of the line voltage was occurring. To observe the cyclical fluctuation, the sweep frequency of the oscillograph was decreased, and the pattern observed is shown in Figure 10. The fluctuation was of the order of ½ of 1% at a frequency of about 5 cps. Superimposed upon this cyclical line-voltage variation are transients or "line bops" which occur at random intervals whenever loads are suddenly applied or removed from the line.

By using a continuous-motion recorder such as the Type 314-A Oscillograph-record Camera, the line voltage can be monitored for any period of time to determine how frequently such transients occur and perhaps to correlate this information with the effects of these transients on various types of equipment being operated from the line.

The circuit of Figure 11 was constructed at Du Mont Laboratories in order to observe and measure the effects of line-voltage variations on cathode-ray oscillographs and television receivers. The circuit as shown consists of a modification of the Type 264-A Voltage Calibrator, so that the calibrator's output voltage could be used for calibrating the amplitude of line fluctuation.

The method described for measuring minute line-voltage variations has considerable application. For example, in the case of fluorescent lamps, a condition sometimes exists where annoying flicker is encountered although there are no changes in line voltage measurable by present methods. This condition may be in the lamp itself, but before this can be determined, the effect of minute variations in line voltage must be determined.

In the case of high-gain video amplifiers, as used in television receivers and cathode-ray oscillographs, certain line-voltage variations give rise to much more noticeable flicker and instability on the screen than others. This occurs when the internal impedance of the power supplies in the equipment is such that feedback through the supply is at a maximum at these power-line surge frequencies. Fluctuations at low frequencies are sometimes introduced by hunting in the power generators. Also, they may be due to cyclical variations in load such as exist at pumping stations.

Amplifier Characteristics — Diode clippers may also be used in the testing of audio amplifiers in conjunction with a sinewave generator.[4] This technique re-

4 See "Techniques for Distortion Analysis". Samuel Sabaroff in ELECTRONICS, June, 1948.

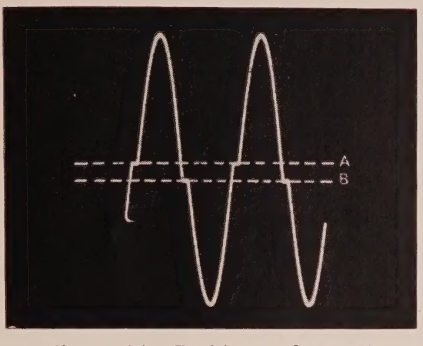


Figure 14. Positive and negative clipping points (A and B) are displaced when signal is passed through an amplifier having phase shift.

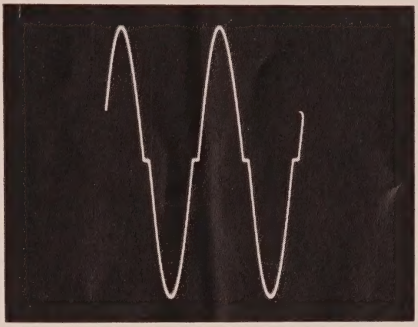


Figure 15. When the signal is passed through an amplifier having negligible phase shift, the clipping points are not visibly displaced.

sembles the square-wave testing technique but eliminates the use of an expensive square-wave generator. This is frequently advantageous since sinewave generators are readily available. By clipping either the positive or negative portions of a sinewave, a flat-top signal can be obtained which is useful in evaluating the frequency-response characteristics of an amplifier. For example, Figure 12 shows the result of a clipped sinewave being applied to an amplifier of poor low-frequency response. Note the tilt in the flat top. Figure 13 shows the same signal from the output of an amplifier having good low-frequency response.

The advantage of this technique over the standard square-wave testing is that, if the amplifier is overloading, the square-wave response will appear to be better than it actually is. But the sinewave portion of the partially clipped wave will show distortion when overloading occurs.

This clipping technique can also be used for observing the phase shift in an amplifier by using a positive and negative clipping circuit. This is illustrated in Figures 14 and 15. The positive and negative clipping points are displaced in the amplifier having phase shift (Figure 14), and are not displaced in the amplifier having negligible phase shift (Figure 15).

The basic circuits described above are examples of the simple manner in which many problems in oscillography can be solved merely by connecting a suitable accessory circuit to the oscillograph.

DU MONT DISPLAY

(*Continued from P. 2*)

extremely high writing rates. Also demonstrated were the Du Mont Type 250-H Cathode-ray Oscillograph and the Du Mont Type 2542 Projection Lens assembled together in a special projection unit.

The new Du Mont Type 5XP- high-sensitivity, high-voltage cathode-ray tube, too, was on exhibit.

An example of the special products designed and developed by the Du Mont Tube Division was a twelve-inch cathode-ray tube containing two independent electron guns.

The Special Products Section of the Instrument Division was represented by the Du Mont Type 319 Cathode-ray Indicator, a special modification of the Du Mont Type 281-A Indicator, equipped with the Du Mont Type K1033 Cathode-ray Tube. This specially designed tube contains a beam trap to permit the beam to be on for an extended period of time without burning the screen. This eliminates the delay otherwise incurred in "gating" the beam on, which might result in the loss of important components in the signal. This special instrument also included circuits for automatically advancing film in an oscillograph-record camera.

TABLE OF CONTENTS . . . Vol. 1, No. 1 – Vol. 10, No. 4

Due to numerous requests by our readers we are publishing the complete Table of Contents of the *Oscillographer* from Vol. 1, No. 1 through Vol. 10, No. 4. In the future the last number of each volume of the *Oscillographer* will contain the complete index for that volume.

PAGE

Vol. 1, No. 1 — March, 1937

A Single Stroke Sweep for the Cathode-Ray Oscillograph 1
Black & White Screens for Television Reception 3
A New Gaseous Discharge Tube 3

Vol. 1, No. 2 — April, 1937

The Cathode Ray Oscillograph Makes Possible a New Instrument for the Music Field 1
New Du Mont Two Inch Cathode-Ray Tube Type 24-XH 2
Advance Announcement of the New DuMont Type 164 Three-Inch Oscillograph 3

Vol. 1, No. 3 — May, 1937

The Photography of Recurrent Phenomena with the Cathode-Ray Oscillograph 1

Vol. 1, No. 4 & 5 — June & July, 1937
(Out of Print)

A New Five-Inch All-Purpose Cathode-Ray Oscilograph — The Type 168 1
Seven Years of Progress in Oscillograph Design 8

Vol. 1, No. 6 & 7 — Aug. & Sept., 1937
(Out of Print)

Europe Turns That Television Corner 1
Oscillograph Amplifier Design 4

Vol. 1, No. 8 & 9 — Oct. & Nov., 1937

The Cathode-Ray Oscillograph Applied to Materials Testing 1
New Cathode-Ray Book Available .. 2
Two New Cathode-Ray Tubes Especially Designed for Television .. 3
Memory Machine Aids Research 4

Vol. 1, No. 10 & 11 — Dec. 1937-Jan. 1938

The Phasmajector 1

PAGE

The Cathode-Ray Oscillograph Applied to the Study of Grid Controlled Power Rectifiers 4

Vol. 1, No. 12 — February, 1938

The Type 171 Oscillograph 1
Oscillograph Pick-Up Units 2

Vol. 2, No. 1 & 2 — March-April, 1938
(Out of Print)

Type 169 Nine-Inch Laboratory Oscillograph 1
The Du Mont Simplified Television System Demonstrated 5

Vol. 2, No. 3 & 4 — May-June, 1938
(Out of Print)

Type 164 Oscillograph 1
Type 168 Oscillograph 2
Type 169 Oscillograph 3
Type 171 Oscillograph 5
Type 156 Oscillograph 5
Type 150 Electronic Switch 6
Television Demonstration Equipment 7
Type 165 Resonoscope 8
Du Mont Cathode-Ray Tubes 9
Du Mont Type 128-A Gaseous Discharge Tube 10
Du Mont Type 885 Gaseous Discharge Tube 10
Du Mont Type 879 Half-Wave High-Vacuum Rectifier Tube 10
The Phasmajector, Type No. 1 12
Special Apparatus 12

Vol. 2, No. 5 & 6 — Aug.-Sept., 1938

The Cathode-Ray Tube Polarograph 1
French Railway Company "Paris-Orleans" Uses Du Mont Cathode-Ray Tubes 4

Vol. 2, No. 5 & 6 — Oct.-Nov., 1938

A Dual-Purpose Electronic Switch .. 1

Vol. 2, No. 6 & 7 — Dec. 1938-Jan. 1939

Intensifier Type Cathode-Ray Tubes 1

PAGE

Du Mont Television Receivers 2
Type 189 Movable Table 3
Cathode-Ray Tube Wall Chart 4

Vol. 2, No. 12 — Vol. 3, No. 1 — Feb.-Mar.-April, 1939
(Out of Print)

Type 175 Cathode-Ray Oscillograph 1

Vol. 3, No. 2 & 3 — April-May, 1939

A New Synchronizing-Signal Generator for Television Transmitting Stations 1

Vol. 3, No. 4 & 5 — June-July, 1939
(Out of Print)

Production Test of Ignition Coils with the Cathode-Ray Oscillograph 1

Photographic Records from Cathode-Ray Tube Screens 4

Vol. 3, No. 6 & 7 — Aug-Sept., 1939

The Amplification of Direct-Current Signals through Alternating-Current Circuits 1

A New Stimulator for Brain-Surgery and Research 6

Vol. 3, No. 8 & 9 — Oct.-Nov., 1939

Study of Phase Displacement in Electrical Circuits from Linearly Expanded Lissajous Figures — Part I 1

Vol. 3, No 10 & 11 — Dec. 1939-Jan. 1940

Study of Phase Displacement in Electrical Circuits from Linearly Expanded Lissajous Figures — Part II 1

Vol. 3, No. 12 — Vol. 4, No. 1 — Feb.-March, 1940

Oscillograph-Study of Ignition-Coil Characteristics 1

Recent Improvements in Types 175 and 175-A Cathode-Ray Oscillographs 4

Vol 4, No. 2 & 3 — April-May, 1940

A New Cathode-Ray Oscillograph — The Type 208 1

Cathode-Ray Symposium Prize Contest 8

PAGE

Vol. 4, No. 4 & 5 —— June-July, 1940
(Out of Print)

A Cathode-Ray Stopwatch 1

Vol. 4, No. 6 & 7 — Aug.-Sept., 1940
(Out of Print)

Oscillographic Method of Measuring Positive-Grid Characteristics 1

Vol. 4, No. 8 & 9 — Oct.-Nov., 1940

The Cathode-Ray Oscillograph as a Means of Demonstrating Elliptically Polarized Light 1

Vol. 4, No. 10 & 11 — Feb.-March, 1941

A Single-Sweep Stopwatch and Its Use In a Biological Problem 1

Vol. 4, No. 12 — Vol. 5, No. 1 — April-May, 1941

Dynamic Balancing of Small Rotors by Means of the Cathode-Ray Oscillograph 1

Mezger Called to Active Duty in U. S. Navy 3

Cathode-Ray Symposium and Prize Contest Extended 4

Vol. 5, No. 2 & 3 — Aug-Sept., 1941

Magnetic Flux Measurement with a Cathode Ray Oscillograph 1

Vol. 5, No. 4 & 5 — Oct.-Nov., 1941

Capacity Comparison Using a Cathode-Ray Tube 1

Type 215 Low-Frequency Linear-Time-Base Generator 2

The "Blackout" Panel for Type 208 Cathode-Ray Oscillograph 4

Vol. 5, No. 6 & 7 — Dec., 1941-Jan., 1942

The Oscillograph Used for Dynamic Balancing — Part I 1

Vol. 5, No. 8 & 9 — Feb., Mar., 1942
(Out of Print)

The Oscillograph Used for Dynamic Balancing — Part II 1

Vol. 5, No. 10 — December, 1942

New Type Numbers for Du Mont Cathode-Ray Tubes 1

Du Mont Reference Manual Available Shortly 3

Vol. 5, No. 11 & 12 — Jan.-Feb., 1943

Notes on Replacing Du Mont Gas Triode Tubes 1

General Scheduling Order M-293 3

Test Equipment Bench 4

Vol. 5, Nos. 11, 12, 13, 14 — March, April, May, June, 1943

Cathode-Ray Bibliography 1

Vol. 6, Nos. 3, 4, 5, 6 — July, Aug., Sept., Oct., 1943

The Oscillograph as a Production Tool 1

Vol. 6, No. 7 — Nov.-Dec., 1943

Sweep Calibration with Low Frequency Standards 1

DISCONTINUED TEMPORARILY

Vol. 7, No. 1 — Jan.-Feb., 1945

Magnification of Details in a Complex Wave Form 1

Vol. 7, No. 2 — Mar.-April, 1945

Cathode-Ray Q-Meter 1

Vol. 7, No. 3 — May-June, 1945

Transmission-Line Measurements 1

Vol. 7, No. 4 — July-August, 1945

High Speed Photographic Recording and Projection Oscillography with the New Du Mont Type 5RP Multi-band Tube 1

Vol. 7, No. 5 — Sept.-Oct., 1945

The Du Mont Type 5SP Dual-beam Cathode-ray Tube 1

Vol. 7, No. 6 — Nov.-Dec., 1945

The Du Mont Cyclograph 1

Vol. 8, No. 1 — Jan.-Feb, 1946

Valve Gear Problems 1

Vol. 8, No. 2 — March-April, 1946 (*Out of Print*)

Some Extended Uses of the Cathode-Ray Oscillograph 1

Vol. 8, No. 3 — May-June, 1946

Uses of the Cathode-ray Oscillograph in Transmitter Adjustment and Control 1

The Du Mont Type 213-A Modulation Monitor 11

Simultaneous Presentation of Two Signals 12

Vol. 8, No. 4 — July-August, 1946

A New Oscillograph for Recording High-Speed Transients — Type 247-A 1

The Du Mont Type 263-A High-Voltage Power Supply 2

The Du Mont Type 274 Cathode-ray Oscillograph 3

Notes on Attenuator Distortion 4

Vol. 8, No. 5 — Sept.-Oct., 1946

The Cathode-Ray Oscillograph as a Signal Generator 1

Vol. 8, No. 6 — Nov.-Dec., 1946

Type 2088 Projection Lens 1

New Du Mont Plant 4

Vol. 9, No. 1 — Jan.-Feb., 1947

A High-Voltage, High-Speed Oscillograph 1

Vol. 9, No. 2 — March-April, 1947

A New Oscillograph Accessory for Direct Measurement of Signal Amplitude — Type 264-A Voltage Calibrator 1

Du Mont Advertising Man Honored by France 3

New Oscillographs Introduced at IRE Show 4

Vol. 9, No. 3 — May-June, 1947

The Type 280 Cathode-Ray Oscillograph 1

Cathode-Ray Tube Wall Chart 8

Vol. 9, No. 4 — July-August, 1947

An All-Purpose Screen for High-Voltage Cathode-Ray Tubes 1

A New Method of Testing Audio Equipment 6

Du Mont Demonstration Room 8
Reorganization of Service Department 8

Vol. 9, No. 5 — Sept.-Oct., 1947
The Du Mont Type 275-A Cathode-Ray Polar-Coordinate Indicator 1

Vol. 9, No. 6 — Nov.-Dec., 1947
The Du Mont Type 281 Cathode-Ray Indicator and the Type 286 High-Voltage Power Supply 1

Vol. 10, No. 1 — Jan.-March, 1948
The Du Mont Type 271-A Oscillograph-record Camera 2
Scheraga Addresses Textile Group .. 7
New CRO Equipment Demonstrated at NEC 8
Bibliography 8

Vol. 10, No. 2 — April-June, 1948
The Du Mont Type 256-D Cathode-ray Oscillograph 2
Pressure-Time Characteristics 6
Notes on Operation of the Type 281 Cathode-ray Indicator at Maximum Writing Rate 8
Servicing with Du Mont Instruments 10
Bibliography 11

Vol. 10, No. 3 — July-Sept., 1948
The Du Mont Type 279 Dual-beam Cathode-ray Oscillograph 2
Cathode-ray Oscillograph Applications in the Textile Field 7
Operating Note on the Type 248 Cathode-ray Oscillograph 9
Bibliography 10

Vol. 10, No. 4 — Oct.-Dec., 1948
A New, Versatile Oscillograph Accessory for the Cathode-ray Oscillograph — Type 314 2
Bibliography 15

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